Improving the use of satellite observations for ocean data assimilation with a reduced rank smoother

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Introduction

Data assimilation for oceanography widely use satellite observations such as altimetric tracks. Stochastics methods such as the Kalman filter often run sequentially: the numerical model propagates the ocean state through time, and an analysis is performed on a regular basis, using the available observations data. Such a configuration allows the use of past, present, but not subsequent observations. Then, for a given analysis, only tracks available at that time will be used, disregarding the forthcoming, sometimes complementary observations.

To improve the coverage of observation tracks for data assimilation, optimal smoothers might be introduced and allow the use of subsequent observations for a given analysis time. Here, the implementation of the SEEK smoother with a high resolution model configuration of the Tropical Atlantic ocean is presented. This region is of specific interest due to the presence of Tropical Instability Waves (TIW): fast oscillations travelling from East to West, and difficult to track with a ‘forward-only’ data assimilation method faced with uncomplete observations such as along-track altimetric measurements. We present these aspects here.

I. Experimental scheme

1.1 Model and observations

We use a Tropical Atlantic configuration (TATL4) of the ocean model NEMO025 (figure 1). Two particular regions may be noted: the Tropical Instability Waves zone in the center of the basin, and the North Brazil zone where eddies may develop. Tests on the smoother are performed using twin experiments. A “true” sequence of ocean state is defined as year 2005. We extract observations from this year. An example is given in figure 2: satellites tracks of Sea Surface Height, SSH, (Jason type), and T/S profiles (profilers type ARGO). A “false” state is built with an error on the initial condition. We first let the model equilibrate with the forcing fields during 2 months (in the beginning it converges quickly by his own); then, when the convergence slows down, we start assimilation experiment.

1.2 Data assimilation experiment

The experiment starts on June 25 (Julian day 20252) and lasts 30 days. The free ocean state is analysed by the SEEK filter (Pham 1998) using observations available every 2 days. A Kalman smoother (Cosme 2010) is applied and performs several retrospective analyses, using cross-time error statistics and observations distributed in time.

Figure 2 shows the altimetric observations available on June 25, as used by the filter for the ocean state estimation. Figure 3 shows the following satellite tracks used by the smoother for the estimation on the same day. The coverage of observations is improved thanks to the smoother.

II. Results

II.1 Reducing global RMS error

The smoother has shown good skills to reduce global RMS errors of assimilated variables (SSH, temperature and salinity) and of the dynamics (velocity). Figure 4 shows an example for the SSH and meridional velocity. The smoothed reanalysis (black cross) are closer to the reference than the filtered solution (black line).

II.2 Smoothing the analysed solution

The smoother increase the spatial coverage of observations at a given time. It is then able to produce analysis states more homogenous as shown on figure 5. It is then a useful tool to produce reanalyses spatially smoothed. Thus the solution is more realistic and prevent potential inconsistent structures.

II.3 “Stability” of analysed states

We also tested the ability of analysed solutions (from the filter and the smoother) to represent the dynamics of the basin. A simple test is carried out on that purpose: we used the analysed states to restart the model and we observed each trajectories (figure 7).

It is shown that the smoothed states are more consistent with the dynamics. The free run initialised with the smoothed states show a trajectory closer to the reference, especially in the North Brazil zone where the dynamics is very sensitive to the initial condition. These results are consistent with the results II.2 that suggested that the smoothed solution provides solutions with more spatially homogeneous errors.

Conclusion

The smoother has been successfully implemented in a realistic ocean circulation configuration. It has shown strong skills to use more efficiently observations scattered in time, like satellite tracks of SSH. Reanalyses from the smoother are more realistic and consistent than the ones from a filter. The residual error from the smoother analysis is lower as we have seen in results II.1. Another aspect of the improvements is the spatially smoothed solution that prevent inconsistent structures (results II.3). Finally, we saw in results II.3 that the dynamics in the smoothed solution is closer to the reference than the one from the filtered solution.

When observations are quite dispersed in time or space, the smoother is a useful tool to extend the influence of subsequent observations to the past and then improve the coverage of the observations for reanalysis purposes. It uses the observations in an optimal way, introducing temporal correlations (compare to the filter that only use spatial correlations). In conclusion, we strongly recommend to implement smoothers to get more realistic and coherent reanalysis.

Références :
